MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

EPM4066 – ROBOTICS AND AUTOMATION

(ME)

7 MARCH 2020
2:30PM - 4:30PM
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 6 pages including cover page and appendix with 4 Questions only. DH-parameter procedures are included in Appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Define the term of "Direct Kinematics" and "Homogenous Transformation".

[4 marks]

(b) A manipulator with four degrees of freedom at its home position is shown in Fig. Q1. All the joints are revolute joints.

(i) Determine the frame assignment.

[6 marks]

(ii) Determine the joint link parameter.

[6 marks]

(iii) Obtain the overall homogeneous transformation matrix at home position $q = [0, 0, 0, -\pi/2]$.

[9 marks]

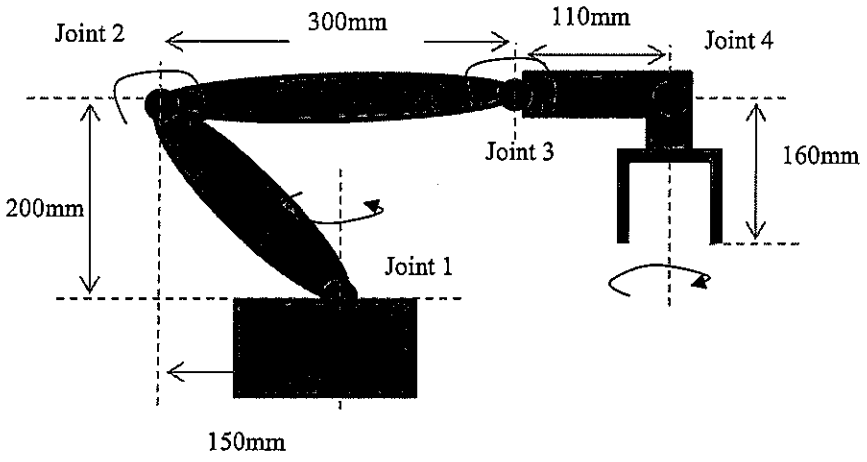

Fig. Q1

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Question 2

(a) Consider the top view of a robotic workstation, with parts A and B, as shown in Fig.Q2. Suppose the centroid of part A has coordinates $[4, 9, 3]^T$ and the centroid of part B has coordinates $[8, 5, 4]^T$.

(i) Find the arm matrix value T_{base}^{pick} needed to pick up part A from above by grasping it in the middle of the long sides.

[3 marks]

(ii) Find the arm matrix value T_{base}^{pick} needed to pick up part B from above by grasping it in the middle of the long sides.

[4 marks]

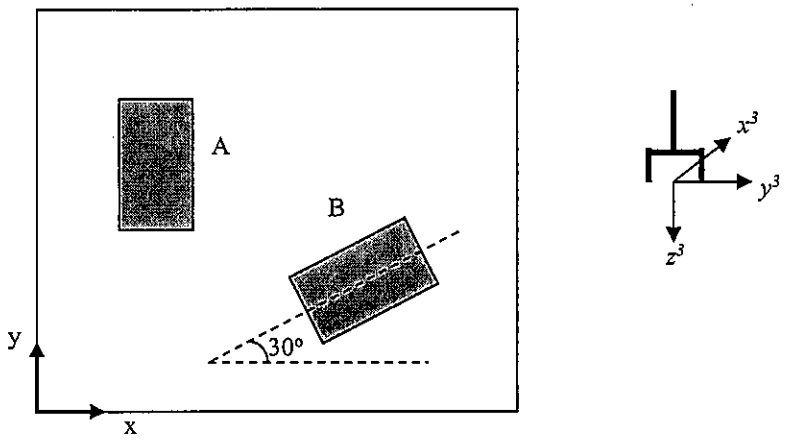

Fig. Q2

(b) Briefly explain the three safety zones with sketch in a work cell.

[4 marks]

(c) What are the factors to be considered in calculating the gripping force?

[5 marks]

(d) One of the joints of an articulated robot has moved from initial angle of 30^0 to a final angle of 75^0 in 5 seconds. The robot starts from rest, and it has a final velocity of 3 degrees/sec. Calculate the coefficients for a third order polynomial joint space trajectory and hence, determine its initial and final joint accelerations.

9 marks]

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Question 3

(a) Briefly describe the working of any two contact sensors used in robotics. Give application examples for each.

[5 marks]

(b) Define Artificial Intelligence and how it demonstrates in several ways.

[5 marks]

(c) Consider the link-coordinate diagram of a 3-axis articulated robot as shown in Fig.Q3. The arm matrix for this robot is given by:

$$T_{base}^{tool} = T_0^1 T_1^2 T_2^3$$

$$= \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ S_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C_3 & 0 & S_3 & 0 \\ S_3 & 0 & -C_3 & 0 \\ 0 & 1 & 0 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Find:

(i) The manipulator Jacobian matrix, $J(q)$.

[10 marks]

(ii) The joint torques and forces if an external force and moment vector, $F^{tool} = [0, 0, f_3, n_1, n_2, n_3]^T$ is applied at the tool tip.

[5 marks]

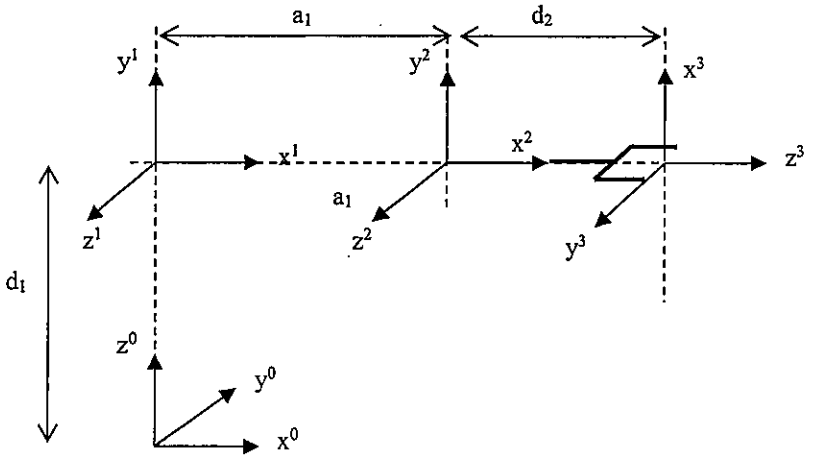

Fig.Q3

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Question 4

(a) Briefly explain the following types of productions.
   (i) Programmable Automation
   (ii) Flexible Automation

[4 marks]

(b) Write any five good reasons for companies undertake project in automation.

[5 marks]

(c) A manufacturing company plans to invest on a new automation machine which will cost RM100,000. The cost of operating and maintaining the automation machine will be roughly RM30,000 per year. The expected revenue is estimated as RM60,000 per year for 7 years. At the end of 7 years, the machine will be scrapped at zero salvage value.

Determine:

(i) Payback period/ROI (Return of Investment) in years.

[3 marks]

(ii) The equivalent uniform annual cost for the project. By using rate-of-return criterion of 20% determine the equivalent present worth of the proposal.

[3 marks]

(d) A manually operated production machine costs RM 50,000. It will have a service life of 10 years with a negligible salvage value at end of its service life. The machine produces parts at a rate of 25 units / hour. The annual maintenance cost for the machine is RM 5,000. A machine overhead rate of 10% is applicable to capital cost and maintenance. Labor to run the machine costs RM 10.00 / h and the applicable overhead rate is 25%. Determine the profit break-even point if the value added is RM2.50 / unit and the rate-of-return criterion is 20%.

[10 marks]

Continued...

Appendix

DH-Parameters for frame assignment estimation of robot

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set $k=1$.
3. Align z^k with the axis of joint $k+1$.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set $k=1$.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

End of Paper